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TITLE: AUDIO PROCESSING APPARATUS

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AUDIO PROCESSING APPARATUS

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an audio processing apparatus which is suitably applied to reproduction of a stereo audio signal of a multi-channels by means of a headphone device.

Description of the Related Art

Recently, multi-channel signals are used mostly as audio signals (sound signals) of an image of cinema and the like, and such signals are recorded on the assumption that the signals are reproduced by speakers on both sides and at the center of an image or speakers beyond or on both sides of a listener. As a result, a sound source in the image matches with a position of an actually audible sound image, and a naturally widespread sound field is established.

However, in the case where such a sound is appreciated by using a prior headphone device, a sound image by sound input is localized in a head, and an image position does not match with a sound image localized position so that the sound image localization becomes extremely unnatural. Further, the localization positions of sound signals of respective channels cannot be reproduced separately. Needless to say, a case that only a sound of multi-channels such as musical sounds is appreciated has the similar problems, namely, a sound is heard

The output of the left channel obtained by addition in the adder 4L is supplied to an digital/analog converter 5L so as to be converted into an analog audio signal. The converted analog audio signal is amplified by an amplifying circuit 6L for driving a headphone, and the amplified signal is supplied to a speaker unit 7L for a left ear in a headphone device 7.

Further, the output of the right channel obtained by addition in the adder 4R is supplied to a digital/analog converter 5R so as to be converted into an analog audio signal. The converted analog audio signal is amplified by an amplifying circuit 6R for driving a headphone, and the amplified signal is supplied to a speaker unit 7R for a right ear in the headphone device 7.

There will be explained below a principle that an audio signal for stereophonic reproduction is converted into an audio signal for binaural reproduction in the process in the digital processing circuit 3 with reference to FIG. 10. A speaker device SL for the left channel is positioned on a left front side of a listener and a speaker device SR for the right channel is positioned on a right front side. Audio signals for stereophonic reproduction are reproduced respectively from the respective speaker devices. At this time, as for a sound which reaches a left ear of the listener, a sound arrived from the speaker device SL of the left channel has a transfer function H_{LL} , and a sound arrived from the speaker device SR of the right channel has a transfer function H_{RL} . Moreover, as for a sound

which reaches a right ear of the listener, a sound arrived from the speaker device SR of the right channel has a transfer function HRR, and a sound arrived from the speaker device SL of the left channel has a transfer channel HLR.

Coefficient values of the coefficient multipliers of the respective digital filters are set so that the four transfer functions HLL, HLR, HRL and HRR are reproduced according to the operations in the four digital filters 3LL, 3LR, 3RL and 3RR. As a result, two-channel audio signals for stereophonic reproduction are converted into two-channel audio signals for binaural reproduction. In this case, the transfer functions of an impulse response to both ears from the speaker devices of the respective channels are measured in a resonant room, and the coefficient values to be set in the coefficient multipliers of the digital filters are set based on the measured values. FIG. 11 shows one example of the measured impulse response data.

Here, Japanese Patent Publications (Patent No. 2751155 and the like) which have been applied by the inventors of the present invention discloses details of the process for converting the audio signal for stereophonic reproduction into the audio signal for binaural reproduction.

According to the processing apparatus which have been suggested, a sound image is localized outside of a head of a listener. However, more precisely, in the case where an audio signal converted for binaural reproduction is heard by a

headphone, transfer functions from right and left speaker units of the headphone to both ears of the listener function, a characteristic slightly different from the case that a sound is heard from an actual sound source appears.

In addition, the transfer functions from the headphone to both ears of the listener vary with types of a headphone. Therefore, in the case where another type of a headphone is used, there occasionally arises a problem that the localizing state of a sound image varies.

The present invention has been achieved in order to solve the above problems, and it is an object of the invention to be capable of realizing accurate sound image localization similar to that in the case of using speakers when an audio signal for stereophonic reproduction is converted into an audio signal for binaural reproduction and a sound is heard via a headphone.

SUMMARY OF THE INVENTION

The present invention includes: converting means for converting n-channel (positive integral number: $n \geq 1$) audio signals supplied from at least one signal source into two-channel output signals; a pair of correcting filter means to which a pair of two-channel signals converted by the converting means are supplied, the correcting filter means converting a difference of hearing sense due to a difference between right and left characteristics of a headphone; and an output section

for supplying a pair of output signals from the pair of correcting filter means to right and left speaker units of the headphone.

According to the present invention, a difference of hearing sense due to a difference between the headphone characteristics is corrected by the correction filter means so that a sound having the characteristic for binaural reproduction reaches right and left ears of a listener accurately.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram showing an example of a whole structure according to a first embodiment of the present invention;

FIG. 2 is a structural diagram showing an example of an IIR filter;

FIG. 3 is a structural diagram showing an example that a characteristic correcting section is composed of the IIR filter according to the first embodiment of the present invention;

FIG. 4 is a block diagram showing an example of a whole structure according to a second embodiment of the present invention;

FIG. 5 is a block diagram showing an example of a whole structure according to a third embodiment of the present invention;

FIG. 6 is a block diagram showing an example of a whole structure according to a fourth embodiment of the present

invention;

FIG. 7 is a block diagram showing an example of a whole structure according to a fifth embodiment of the present invention;

FIG. 8 is a structural diagram showing one example of a structure of a prior audio processing apparatus;

FIG. 9 is a structural diagram showing one example of a digital filter;

FIG. 10 is an explanatory diagram for explaining an out-of-head sound image localizing process; and

FIG. 11 is a characteristic chart showing an example of impulse response data.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

There will be explained below a first embodiment of the present invention with reference to FIGS. 1 through 3.

In the present embodiment, audio signals for stereophonic reproduction obtained at input terminals 11L and 11R are converted into audio signals for binaural reproduction so as to be supplied to a headphone device connected to this apparatus and be reproduced. FIG. 1 is a diagram showing a whole structure of the present embodiment. A left channel signal and a right channel signal composing a two-channel audio signals for stereophonic reproduction are supplied to the left channel audio signal input terminal 11L and the right channel audio signal input terminal 11R. The audio signals obtained at

the terminals 11L and 11R respectively are converted into digital audio signals by analog/digital converters 12L and 12R for the respective channels.

The converted audio signals of the respective channels are supplied to a signal processing section 13. The signal processing section 13 is a circuit for converting the audio signals into two-channel audio signals forming a sound field for headphone reproduction based on two-system impulse responses from a sound source to the left ear and right ear of a listener. The signal processing section 13 is a circuit based on the principle similar to that of the digital processing circuit 3 shown in FIG. 8 of the prior art, and it is composed of digital filters such as FIR filters, adders and the like. Coefficient values which are multiplied by coefficient multipliers of the digital filters are set based on an actually measured value of a two-system impulse response from the sound source to the left ear and the right ear of the listener. In this case, such respective digital filters can execute very large-scale operations of about several thousand taps, for example.

In the present embodiment, the audio signal of the left channel processed in the signal processing section 13 is supplied to the characteristic correcting section 14L for the left channel, and the audio signal of the right channel processed in the signal processing section 13 is supplied to the characteristic correcting section 14R of the right channel. The

headphone characteristics are corrected respectively in the characteristic correcting sections 14L and 14R. The correction in the characteristic correcting sections 14L and 14R is for correcting a difference of the sense of hearing due to a characteristic difference of a headphone (a headphone device 18, mentioned later) to be used. For example, FIR type digital filters (digital filters having the structure shown in FIG. 9) are used for the correction.

That is, when a transfer characteristic of the left channel from a left speaker unit (driver) incorporated in the headphone attached to a listener to the listener's left ear is H_{hl1} , multiplying coefficients or the like of the respective multipliers composing the filters are set in the filters composing the characteristic correction section 14L for the left channel so that a reverse characteristic of the transfer characteristic H_{hl1} [$1/H_{hl1}$] is superposed as impulse response data on a time area. Moreover, when a transfer characteristic of the left channel from a right speaker unit (driver) incorporated in the headphone attached to the listener to the listener's right ear is H_{lr1} , multiplying coefficients or the like of the respective multipliers composing filters are set in the filters composing the characteristic correcting section 14R for the right channel so that a reverse characteristic of the transfer characteristic H_{lr1} [$1/H_{lr1}$] is superposed as impulse response data on the time area. Here, in the case where the FIR

may be constituted as the correction processing sections 14L and 14R.

There will be explained below a second embodiment of the present invention with reference to FIG. 4. In FIG. 4, the same reference numerals are given to the portions corresponding to those in FIG. 1 described in the embodiment 1, and the detailed explanation thereof is omitted.

Also in the present embodiment, audio signals for stereophonic reproduction obtained at the input terminals 11L and 11R are converted into audio signals for binaural reproduction, and the converted signals are supplied to the headphone device connected to this apparatus so as to be reproduced. In the present embodiment, different two types of headphone devices can be connected to the apparatus.

There will be explained below a structure of the present embodiment. FIG. 4 is a diagram showing a whole structure of the present embodiment. A left channel signal and a right channel signal composing two-channel audio signals for stereophonic reproduction are supplied to the left channel audio signal input terminal 11L and the right channel audio signal input terminal 11R. The audio signals obtained at the terminals 11L and 11R respectively are converted into digital audio signals by the analog/digital converters 12L and 12R for the respective channels. The converted audio signals of the respective channels are supplied to the signal processing

18 attached to a listener to the listener's left ear is Hhl_1 and a transfer characteristic of the right channel is Hlr_1 , a reverse characteristic of the transfer characteristic Hhl_1 $[1/Hhl_1]$ is superposed as impulse response data on a time area in the filter composing the characteristic correcting section 14L for the left channel, and a reverse characteristic of the transfer characteristic Hlr_1 $[1/Hlr_1]$ is superposed as impulse response data on the time area in the filter composing the characteristic correcting section 14R for the right channel.

The right and left audio signals corrected in the characteristic correcting sections 14L and 14R are supplied to digital/analog converters 15L and 15R for respective channels, respectively, so as to be converted into analog audio signals. The right and left analog audio signals of two channels are amplified by amplifiers 16L and 16R for driving a headphone with a comparatively small amplification factor, and are supplied to headphone connection terminals 17L and 17R. The audio is reproduced from the right and left speaker units 18L and 18R of the connected headphone device 18. The above structure and process are the same as those described in the first embodiment.

In the present embodiment, the audio signals of the right and left 2 channels output from the signal processing section 13 are supplied also to second characteristic correcting sections 21L and 21R. As for the structure of the characteristic correcting sections 21L and 21R, they are

composed of filter means such as the FIR type digital filters similarly to the first characteristic correcting sections 14L and 14R, and characteristics to be corrected are different.

That is, when a transfer characteristic of the left channel from a driver incorporated in a headphone device (here, a codeless headphone device 25, mentioned later) to which the audio signals processed in the second characteristic correcting sections 21L and 21R are supplied is H_{hl_2} and a transfer characteristic of the right channel is H_{lr_2} , a reverse characteristic of the transfer characteristic H_{hl_2} [$1/H_{hl_2}$] is superposed as impulse response data on a time area in the filters composing the second characteristic correcting section 21L for the left channel, and a reverse characteristic of the transfer characteristic H_{lr_2} [$1/H_{lr_2}$] is superposed as impulse response data on the time area in the filters composing the second characteristic correcting section 21R for the right channel.

The right and left audio signals corrected in the second characteristic correcting sections 21L and 21R are supplied to digital/analog converters 22L and 22R for respective channels, respectively, so as to be converted into analog audio signals. The right and left analog audio signals of two channels are amplified by amplifiers 23L and 23R so as to be supplied to an infrared signal output section 24. The infrared signal output section 24 is a circuit for outputting the supplied audio

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the present embodiment. A left channel signal and a right channel signal composing two-channel audio signals for stereophonic reproduction are supplied to the left channel audio signal input terminal 11L and the right channel audio signal input terminal 11R, respectively. The audio signals obtained at the terminals 11L and 11R respectively are converted into digital audio signals by the analog/digital converters 12L and 12R for the respective channels, and are supplied to the signal processing section 13. The converted digital audio signals of the respective channels are supplied to the signal processing section 13. The signal processing section 13 is a circuit for converting the digital audio signals into two-channel audio signals forming a sound field for headphone reproduction based on two-system impulse responses from a sound source to the left ear and right ear of a listener. This part of the structure is the ~~completely~~ same as that of the circuit described in the first embodiment.

Thereafter, the audio signal of the left channel processed in the signal processing section 13 is supplied to a first characteristic correcting section 31L for the left channel, and the audio signal of the right channel processed in the signal processing section is supplied to a first characteristic correcting section 31R for the right channel. Headphone characteristics which have assumed the headphone device 18 connected to the headphone connection terminals 17L

and 17R (namely, transfer characteristics from the drivers to both ears of the listener) are corrected in the first characteristic correcting sections 31L and 31R, respectively.

Further, the audio signal of the left channel processed in the signal processing section 13 is supplied to a second characteristic correcting section 32L for the left channel, and the audio signal of the right channel processed in the signal processing section 13 is supplied to a second characteristic correcting section 32R for the right channel. Headphone characteristics which have a codeless headphone device (not shown) are corrected in the second characteristic correcting sections 32L and 32R, respectively. The structure of the respective characteristic correcting sections is the same as that of the characteristic correcting sections described in the first and second embodiments, and filter means such as FIR type digital filters, IIR type digital filters and analog filters are used.

The right and left audio signals corrected in the first characteristic correcting sections 31L and 31R and the right and left audio signals corrected in the second characteristic correcting sections 32L and 32R are supplied to a change-over switch 33. The change-over switch 33 selects one pair of the audio signals based on a control signal obtained at a control terminal 33a so as to output the selected pair of the audio signals. The audio signals output from the change-over switch

33 are supplied respectively to the digital/analog converters 15L and 15R for the respective channels so as to be converted into analog audio signals. The analog audio signals of the two right and left channels are amplified by the amplifiers 16L and 16R and are supplied to the headphone connection terminals 17L and 17R and the infrared ray output section 34. Here, the control signal to be supplied to the control terminal 33a of the change-over switch 33 is generated, for example, based on operation of an operation key provided to this apparatus.

When the headphone device 18 is connected to the headphone connection terminals 17L and 17R, the audio is reproduced from the right and left speaker units 18L and 18R of the headphone device 18. Moreover, when the ~~codeless~~ ^{a cordless} headphone device (not shown) is prepared, the ~~codeless~~ ^{cordless} headphone device receives the infrared signals output from the infrared ray output section 34 and reproduces the received audio.

Here, when the headphone device 18 is used, it is controlled by means of the operation key so that the change-over switch 33 selects output of the first characteristic correcting sections 31L and 31R and the audio signals corrected in the first characteristic correcting sections 31L and 31R are supplied from the headphone connection terminals 17L and 17R to the headphone device 18. Moreover, when the ~~codeless~~ ^{cordless} headphone device is used, it is controlled by the operation key so that the change-over switch 33 selects the output of the first

selected.

Next, There will be explained below a fourth embodiment of the present invention with reference to FIG. 6. In FIG. 6, the same reference numerals are given to the portions corresponding to those in FIGS. 1 and 5 described in the first and third embodiments, and the detailed explanation thereof is omitted.

There will be explained below a structure of the present invention. FIG. 6 is a diagram showing a whole structure of the present embodiment. A left channel signal and a right channel signal composing two-channel audio signals for stereophonic reproduction are supplied to the left channel audio signal input terminal 11L and the right channel audio signal input terminal 11R. The audio signals obtained at the terminals 11L and 11R respectively are converted into digital audio signals by the analog/digital converters 12L and 12R for the respective channels so as to be supplied to the signal processing section

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by controlling the controller 42. When the codeless headphone device is used, the coefficient multipliers of the digital filters in the signal processing section 41 are brought into the second setting state by controlling the controller 42.

a According to this structure, in both the cases where the headphone device 18 is directly connected to the headphone connection terminals 17L and 17R and the ~~codeless~~ ^{cordless} headphone device is used, a difference of the headphone characteristics is corrected suitably so that the characteristics become satisfactory. Here, in the case of the present embodiment, one pair of the signal processing section 41 having digital filters executes the converting process for converting into audio signals for binaural reproduction and the correcting process for correcting the headphone characteristics. For this reason, the circuit configuration can be simplified. Moreover, since one pair of the signal processing section 41 can execute two types of headphone characteristic correcting processes, one pair of the correcting section is sufficient. As a result, the circuit configuration is simplified.

There will be explained below a fifth embodiment of the present invention with reference to FIG. 7. In FIG. 7, the same reference numerals are given to the portions corresponding to those in FIG. 1 described in the first embodiment, and the detailed explanation thereof is omitted.

In the present embodiment, multi-channel audio signals

obtained at input terminals 51L and 51R, 51C, 51SL, 51SR and 51LFE respectively are converted into two-channel audio signals for binaural reproduction, and the signals are supplied to the headphone device connected to the apparatus so as to be reproduced.

There will be explained below a structure of the present embodiment. FIG. 7 is a diagram showing a whole structure of the present embodiment. The multi-channel audio signals supplied to the input terminals in this example are composed of 6-channel audio signals. A left front channel signal (signal of a channel that a sound image is localized in a left front portion) is obtained at the input terminal 51L, a right front channel signal (signal of a channel that a sound image is localized in a right front portion) is obtained at the input terminal 51R, a center channel signal (signal of a channel that a sound image is localized in a center front portion) is obtained at the input terminal 51C, a left rear channel signal (signal of a channel that a sound image is localized in a left rear portion) is obtained at the input terminal 51SL, a right rear channel signal (signal of a channel that a sound image is localized in a right rear portion) is obtained at the input terminal 51SR, and a signal for low-frequency signal channel is obtained at the input terminal 51LFE. Here, in the case of such a channel structure, the low-frequency channel is assumed as a 0.1 channel, and this channel is added to the remaining 5

The left channel audio signal processed in the signal processing section 54 is supplied to the characteristic correcting section 14L for the left channel, and the right channel audio signal processed in the signal processing section 54 is supplied to the characteristic correcting section 14R for the right channel. The headphone characteristics are corrected in the characteristic correcting sections 14L and 14R, respectively. The correcting process in the characteristic correcting sections 14L and 14R here is the same as that described in the first embodiment, and an FIR type digital filter is used.

The right and left audio signals corrected in the characteristic correcting sections 14L and 14R are supplied to the digital/analog converters 15L and 15R for the respective channels so as to be converted into analog audio signals. The right and left two-channel analog audio signals are amplified by the amplifiers 16L and 16R and are supplied to the headphone connection terminals 17L and 17R so that audio is reproduced from the headphone device 18 connected to the headphone connection terminals 17L and 17R.

According to this structure, the multi-channel audio signals form the sound field where sound source is in the positions surrounding a listener who wears the headphone device 18 so that the multi-channel audio signals can be reproduced satisfactorily. In this case, similar to the case of the first

embodiment, the transfer characteristics from the drivers of the headphone to both the ears of the listener are corrected. For this reason, the sound source can be heard from the accurate positions.

Here, the present embodiment has explained the process in the case where 5.1-channel audio signal is input as multi-channel audio signals, but needless to say, the present invention is applicable to a case of multi-channel audio signals having another channel structure.

In addition, in the case where the multi-channel audio signals are reproduced, the processes of correcting a plurality of headphone characteristics described in the second, third and fourth embodiments may be executed simultaneously or selectively.

Further, in the second, third and fourth embodiment, the process for correcting two sets of headphone characteristics can be executed, but a process for executing three or more sets of headphone characteristics may be executed.

